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PORTLAND HABOR SURVEYS, LOWER WILLAMETTE RIVER, SUMMER 1961

Public Health Service
Portland, Oregon

1961

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WORKING PAPER NO. 25

COLUMBIA RIVER BASIN PROJECT
For Water Supply and Water Quality Management

PORTLAND HARBOR SURVEYS

LOWER WILLAMETTE RIVER

SUMMER 1961

Prepared by ENK

Reviewed by JLA

Approved by WWT

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U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Public Health Service
Region IX

Division of Water Supply and Pollution Control
570 Pittock Block
Portland 5, Oregon

This working paper contains preliminary data and information primarily intended for internal use by the Columbia River Basin Project staff and cooperating agencies. The material presented in this paper has not been fully evaluated and should not be considered as final.

PORTLAND HARBOR SURVEYS
LOWER WILLAMETTE RIVER

Introduction

During the summer of 1961, the Public Health Service and Oregon State Sanitary Authority cooperated in several water quality surveys on the lower Willamette River downstream of Oregon City (R.M. 26). The water quality within this reach has been and is of considerable concern to those responsible for the management of the water quality resources of the Willamette Basin.

The Willamette River downstream of Oregon City changes in character from a fairly swift-flowing river to one deep and slow-moving. During the critical summer low-flow period, river stage in the Portland Harbor fluctuates widely with the flood stage of the Columbia River. This rise in river stage adversely affects water quality in the lower Willamette until mid-July with the time of travel, or detention time, approximating twice that of normal low flow. Water quality is further impaired when the river stage rises prior to commencement of lagooning by the various pulp and paper mills in the lower Willamette River. Stream flow in the Willamette River is also declining rapidly at this time while water temperatures are on the increase. One 24-hour diurnal survey was conducted during this period.

After the Columbia River falls to its more natural flow, which generally occurs from the first to the middle of July, water quality in the lower Willamette River becomes more stabilized and not subjected to the rapid fluctuation as those mentioned above. Two 24-hour diurnal surveys were conducted during this period.

Summary

The survey work conducted on the lower Willamette River during the summer of 1961 answered a few of the questions relative to the water quality in this reach, and opened, or stimulated, thought for further study into other areas. The many variables inherent when studying a water body of this type limit the use of conventional stream methods in evaluating its assimilative capacity. Some of these are: wide fluctuations in river stage throughout a critical period as a result of tidal or backwater conditions; highly variable waste loadings; resultant changes in time of flow.

Water quality conditions measured during the three surveys indicated one definite trend from the first through the third survey. The effect of photosynthesis on the surface DO declined markedly from the first survey in June to the last in August. Also noted during each individual survey, was a decrease in the diurnal variation from the upstream Station No. 3 (R.M. 16.5) to the downstream Station No. 1 (R.M. 7.0), as follows:

Diurnal Variation

Date	Station No. 3	Station No. 2	Station No. 1
	MG/L	MG/L	MG/L
Jun 22-23	1.9	1.4	0.4
Jul 27-28	1.9	1.3	0.9
Aug 9-10	1.3	0.3	0.5

This phenomenon could be a result of the increase in color and reduction in the light transmission which would in turn be responsible for the declining plankton population downstream of Oregon City. Visual observations throughout the summer indicated that this was the case, although no plankton measurements were made. There was also a diurnal variation in DO at mid-depth noted at several stations occurring approximately six hours after the peak surface DO. The lag would probably represent the time required for the surface waters, with its higher DO gradient, to mix to this level and reach equilibrium before declining prior to the next diurnal cycle.

Also noted on the first two surveys was the increase in BOD throughout the late afternoon and evening hours. These increases were quite uniform throughout this period, and appear to be significant. The rate of change of BOD during this period approximated the rate of change in the mid-depth DO, reaching a peak at nearly the same time of day. There were a number of ways in which this could be explained, one of which would be due to the indirect measurement of plankton as a result of their vertical movement in the surface water mass throughout the day. This has been observed and measured in other water masses, and appears feasible in studying the BOD and DO data. If BOD determinations had been made of the surface waters, this possibly could have been confirmed.

During the final survey on August 9 and 10, this increase in BOD during the late afternoon and evening hours was very little in evidence. Surface DO concentrations also remained quite stable and reflected little change during the daylight hours. This would indirectly serve as an index of the plankton population and relative productivity of the lower Portland Harbor. In addition, this would serve to further confirm the theory regarding the increase in BOD during two previous surveys.

In studying the water quality data obtained on these three surveys in relation to the tidal stage, as measured by the U. S. Weather Bureau Gauging Station at the Morrison Bridge, there seems to be little correlation. Previous surveys conducted by others in the past have indicated a correlation between tidal stage and water quality. Why this was not evident during the surveys of the past summer is not known at this time.

For monitoring purposes it is quite apparent from studying the data that a mid-depth sample is a much more representative sample than a surface sample. This depth approximated 20 feet at Stations No. 1 and 3, and 35 feet at Station No. 2.

Comparative DO data for the years 1958 through 1961 is plotted on Figure 3, including averages for the three surveys. It will be noted that the 1961 OSSA survey data indicate higher DO concentrations than was measured at mid-depth during the same general period in the diurnal surveys.

Scope of Surveys

A series of 24-hour surveys were conducted on June 22-23, July 27-28, and August 9-10, 1961, on the lower Willamette River from Staff Jennings (R.M. 16.5) to the SP&S Bridge (R.M. 7.0). Sampling station locations were midstream at No. 1 - SP&S Bridge (R.M. 7.0); No. 2 - Steel Bridge (R.M. 12.0); No. 3 - Staff Jennings (R.M. 16.5). The three stations were sampled every two hours at midstream for a 24-hour period. Measurements were made at the surface, mid-depth, and bottom 1/ of dissolved oxygen, biochemical oxygen demand, sulfite waste liquor, pH, and temperature. The BOD and SWL were sampled at mid-depth only. River stage data was made available by the U. S. Weather Bureau which operates a recording water level gage in the Portland Harbor.

Discussion of Survey Results

June 22-23 Survey

On the June 22-23 survey the river stage in the Portland Harbor was between 19.3 and 19.9 feet.

Station No. 3:

At Station No. 3, Staff Jennings, the dissolved oxygen content of the surface waters varied from a low of 3.9 MG/L at 12:00 noon to a high of 5.8 MG/L at 7:00 p.m., a net change of 1.9 MG/L. Dissolved oxygen content at mid-depth, 20 feet in depth, indicated a similar diurnal variation with a high of 6.6 MG/L coming at 1:00 a.m., a lag of some six hours after the peak surface DO.

During the course of the survey, sulfite waste liquor concentration declined at this station by approximately 30 ppm. This may have been

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1/ Not included on the initial June 22-23 survey.

due to the affect of commencement of lagooning by mills upriver, or to mill operation at Oregon City.

Station No. 2:

Water quality at Station No. 2, Steel Bridge, displayed a diurnal pattern similar to that at Station No. 3. Dissolved oxygen at the surface and mid-depth were both less than Station No. 3. The surface DO varied between a low of 3.4 MG/L at 5:00 a.m. to a high of 4.8 MG/L at 9:00 p.m., and at mid-depth between 2.1 MG/L at 7:00 a.m. and 4.6 MG/L at 11:00 p.m.

The 11:00 p.m. mid-depth DO result appears inconsistent with the preceding and following samples. This would also result in an incurrent BOD in that the DO was used as the initial DO for the BOD determination. This is further verified in studying the SWL concentration at this station. The SWL between 9:00 and 11:00 p.m. dropped approximately 50 percent which should result in a somewhat lower BOD, which was not the case.

If the 11:00 p.m. DO was not considered, the next high occurred at 3:00 a.m., again lagging the surface high by approximately six hours.

Explanation of the 50 percent decrease in the SWL concentration between 9:00 and 11:00 p.m. to less than at Station No. 3, can only be hypothesized to be as a result of the operation of the upstream mills and lagooning practices.

Station No. 1:

Water quality at Station No. 1 declined again over that at Station No. 2. There was less diurnal variation in the surface DO's which averaged near 3.8 MG/L. Columbia River water, which is colder and more dense than the Willamette River water, will, if the physical forces are sufficient, be transported to the surface at this station. This phenomenon was observed on several occasions in the vicinity of this station, made evident by the significant variations in turbidity between the two water masses.

July 27-28 Survey

On July 27-28, 1961, the second 24-hour diurnal survey was conducted at the three stations on the lower Willamette River. The only significant change not included in the June 22-23 survey was sampling for DO near the bottom. In studying data obtained on the initial survey, and noting the significant variation from the surface to mid-depth, it was thought desirable to include this in subsequent surveys.

Station No. 3:

Dissolved oxygen at the surface again reflected the effects of photosynthesis throughout the diurnal sampling period. The DO at Station No. 3 at the surface varied from a high of 5.0 MG/L at 5:30 p.m. to a low of 3.1 MG/L at 4:00 a.m., with the DO at mid-depth varying from a high of 4.4 MG/L at 11:25 p.m. to a low of 4.0 MG/L between 2:00 and 4:00 a.m. A DO of 2.7 MG/L which occurred at 7:30 p.m. at mid-depth does not appear to be a representative sample and was not considered.

Sulfite waste liquor concentrations remained quite stable, varying between 76 and 106 ppm with a mean of 80 ppm.

There was gradual increase in BOD at this station throughout the sampling period, paralleling the mid-depth DO curve.

Station No. 2:

The surface DO at Station No. 2 again followed a diurnal pattern similar to that at Station No. 3, varying from a low of 3.5 MG/L at 8:45 a.m. to a high of 4.8 MG/L at 4:30 p.m. DO at mid-depth and near bottom did not reflect any significant diurnal fluctuation and averaged near 3.5 MG/L. As at Station No. 3, the BOD increased throughout the day from 1.9 MG/L at 7:00 a.m. to 3.1 MG/L at 3:45 a.m.

Sulfite waste liquor concentration remained quite stable throughout the entire survey period, averaging near 85 ppm. It would appear that the indicated increase in the BOD was not as a result of any change in the SWL concentration.

Station No. 1:

The DO concentration at Station No. 1 were somewhat erratic. Surface DO's indicated two apparent diurnal fluctuations but are of little significance. The BOD at mid-depth increased during the evening and early-morning hours, but the change was not as emphatic as the two upstream stations. SWL concentration fluctuated very little and averaged near 80 ppm.

There were no apparent fluctuations in water quality throughout the tidal cycle as measured at the Morrison Bridge in the lower Portland Harbor.

August 9-10 Survey

The third and final 24-hour water quality survey of the three sampling stations was made, beginning at 7:00 a.m., August 9, 1961, and concluded at 6:00 a.m. on August 10, 1961.

All stations sampled during this survey experienced little variation in water quality throughout the period sampled.

Station No. 3:

Station No. 3 exhibited what might be considered a slight diurnal fluctuation in the surface DO. Mid-depth and bottom DO increased gradually from approximately 4.0 to 4.8 MG/L. The mid-depth BOD was erratic with the few samples that were taken and were not meaningful. Sulfite waste liquor concentration declined gradually throughout the sampling period from 54 to 38 ppm.

Station No. 2:

The surface DO at Station No. 2 declined steadily from the beginning to the end of the sampling period. Mid-depth and bottom DO results were essentially equal to the surface, only varying a maximum of 0.4 MG/L greater during the late afternoon. Increasing SWL concentration at this station during the survey could account for the uniform decline of approximately 0.7 MG/L in the DO. SWL increased from 53 ppm at 6:00 a.m. on August 9 to 90 ppm at 4:00 a.m. on August 10.

Station No. 1:

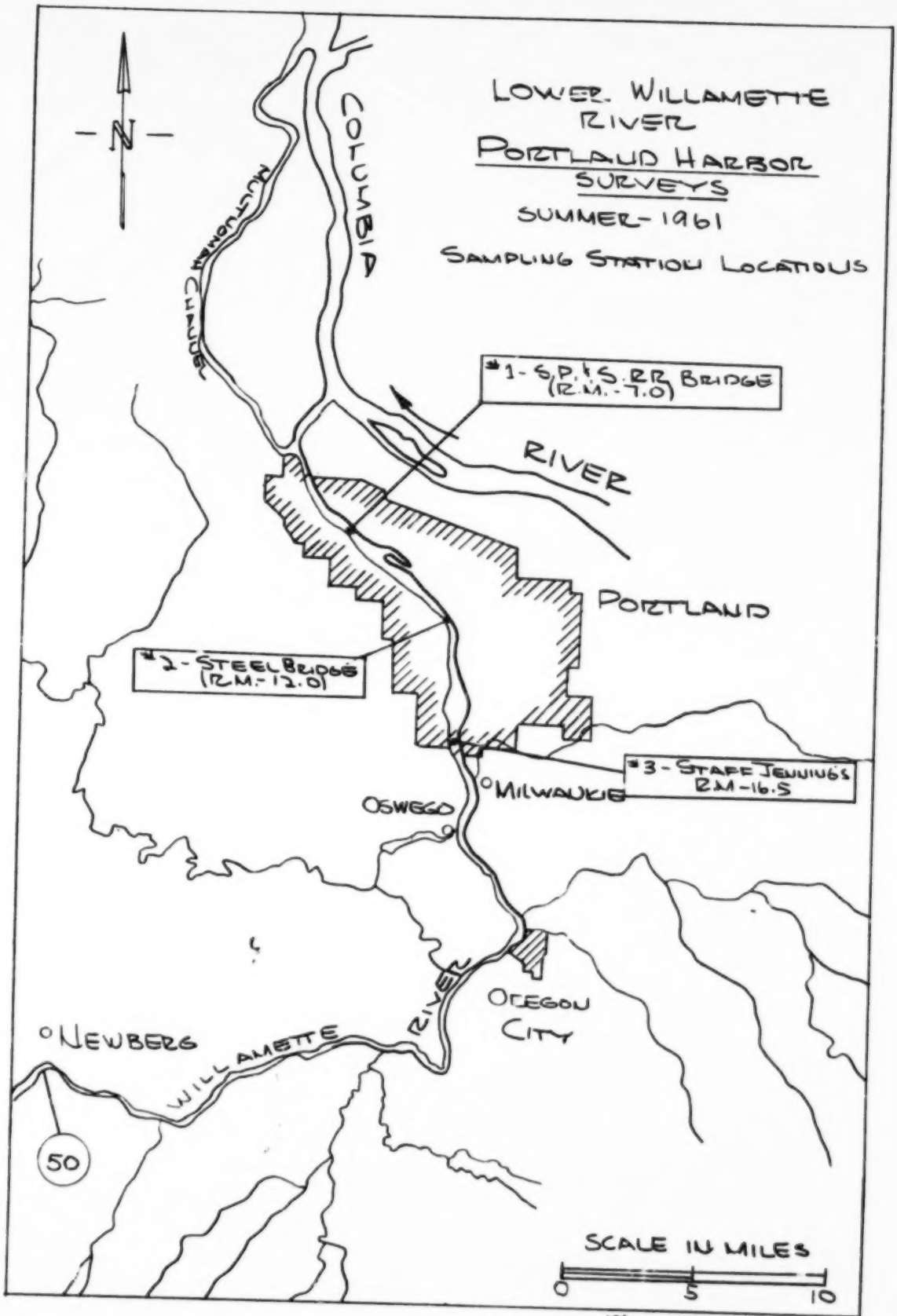
The DO at Station No. 1 was very similar to that at Station No. 2. A general decline in DO of some 0.3 MG/L was experienced at the three depths sampled. BOD remained fairly constant, declining during the last 12 hours some 0.75 MG/L. SWL was somewhat erratic while increasing from approximately 60 to 75 ppm.

In studying the data obtained on this survey, there appears to be little, if any, correlation between the tidal stage and the water quality as measured during the survey.

General

The pH measurements were not plotted or considered in the above discussion due to the numerous breakdowns and difficulties experienced with the field meter during the surveys.

A summary of the mean DO, BOD, and SWL data taken on the three surveys is plotted in Figures 1 and 2.


LOWER WILLAMETTE RIVER
PORTLAND HARBOR SURVEYS
SUMMER-1961
SAMPLING STATION LOCATIONS
N
COLUMBIA
MULTNOMAH CHANNEL
*1 - S.P. & S. RR BRIDGE (R.M. - 7.0)
RIVER
PORTLAND
*2 - STEEL BRIDGE (R.M. - 12.0)
*3 - STAFF JENNINGS R.M. - 16.5
MILWAUKIE
OSWEGO
OREGON CITY
NEWBERG
WILLAMETTE RIVER
50
SCALE IN MILES
0
5
10

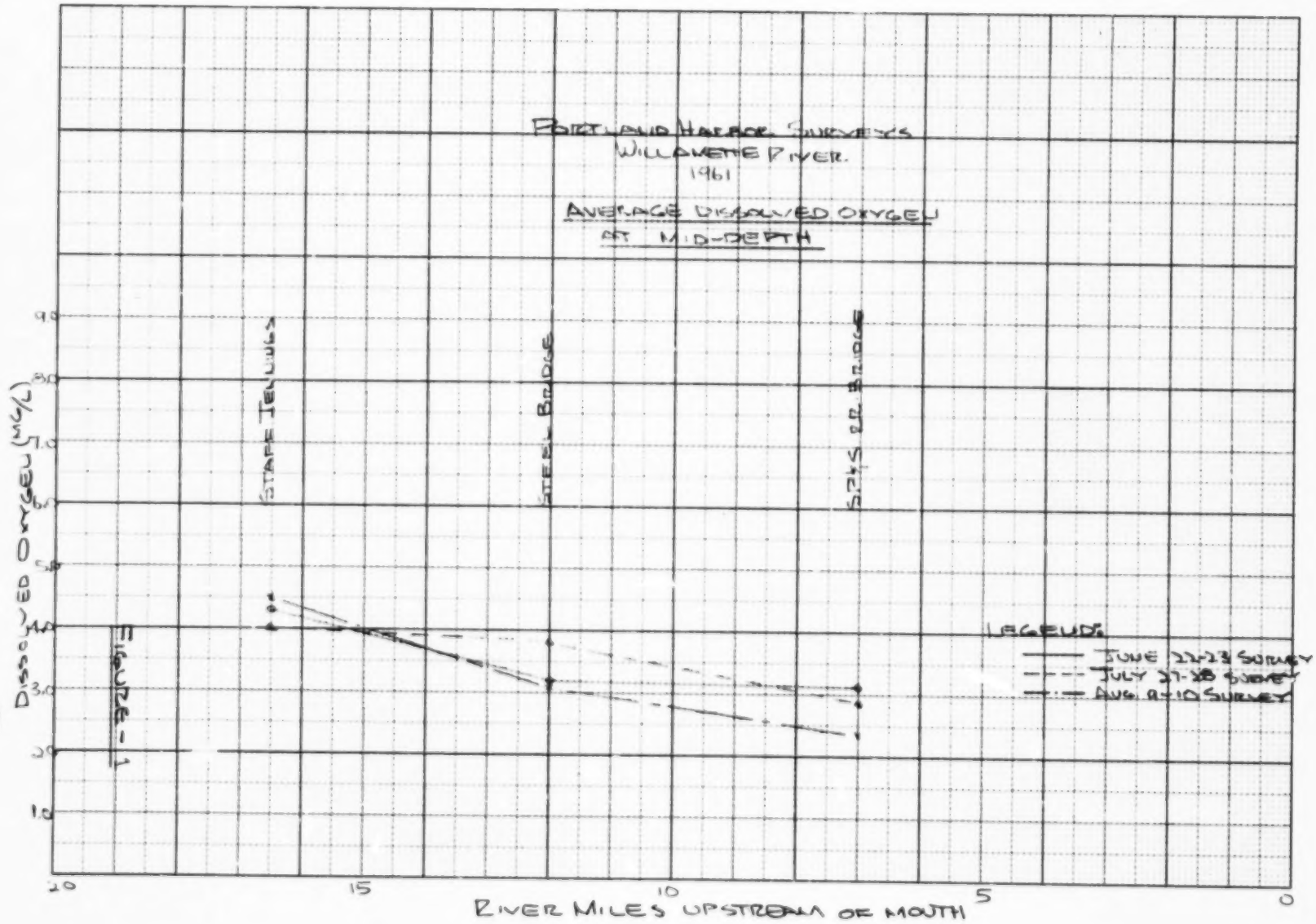
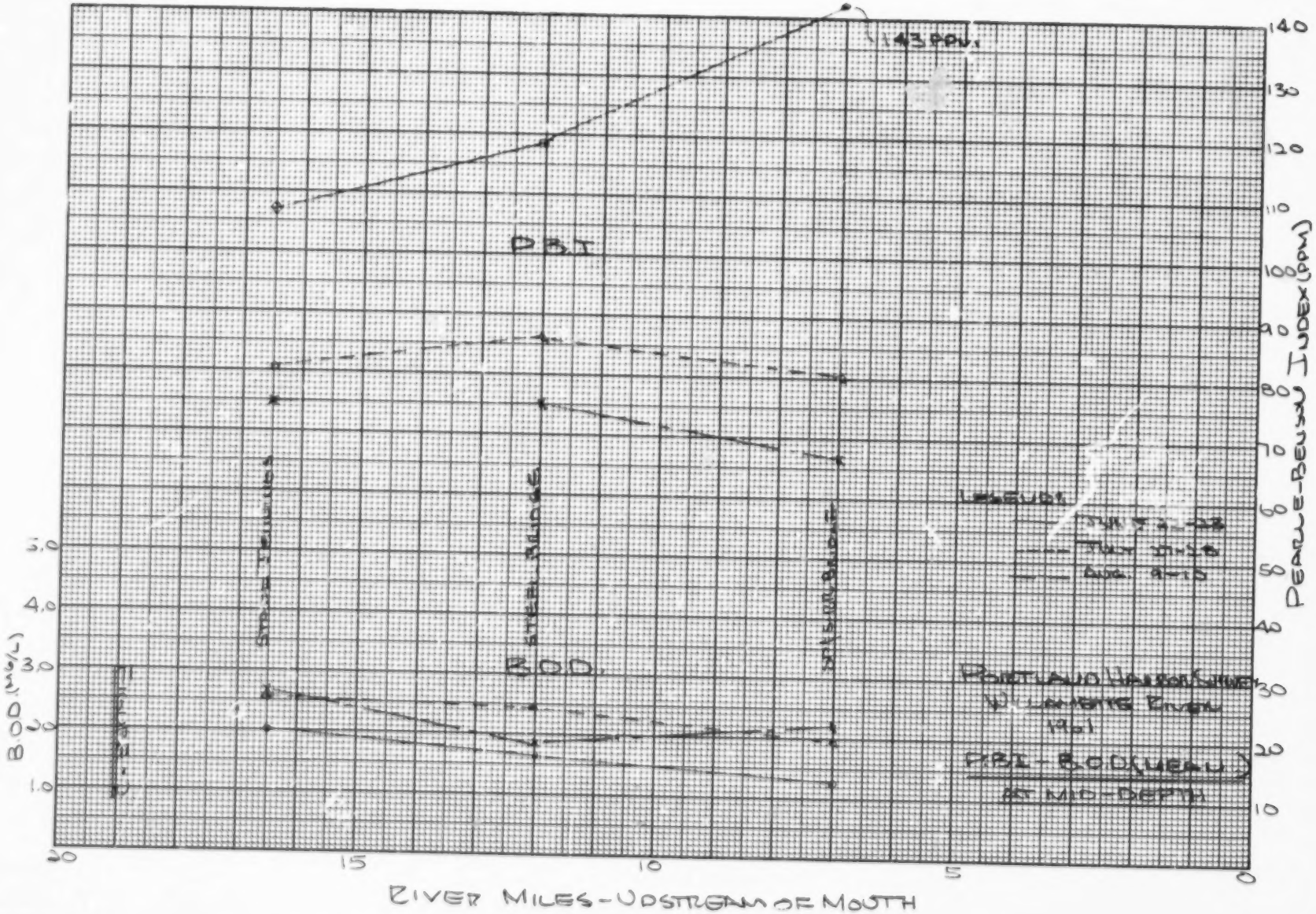
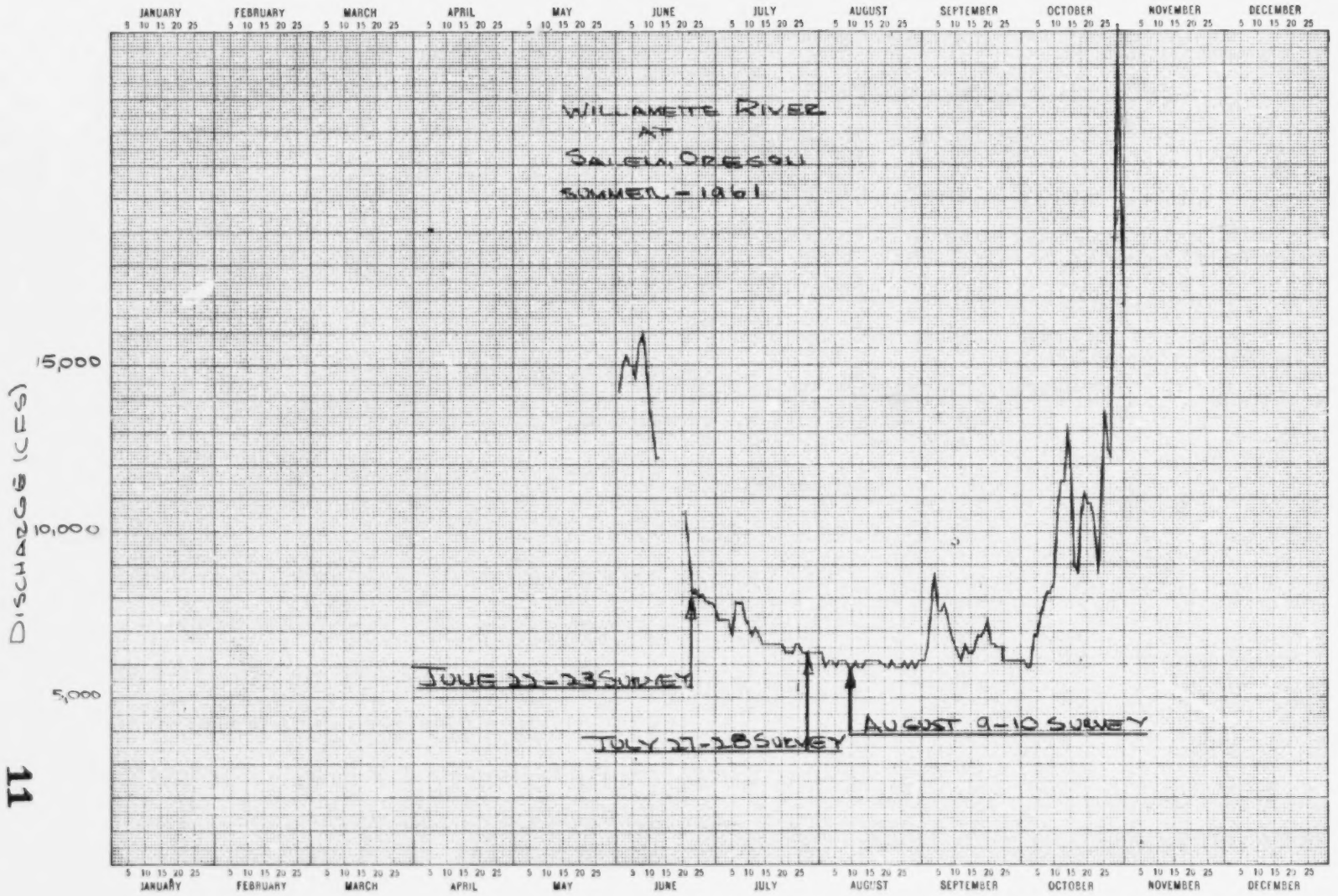

PORTLAND HARBOR SURVEYS
WILLAMETTE RIVER.
1961
AVERAGE DISSOLVED OXYGEN
AT MID-DEPTH
DISSOLVED OXYGEN (MG/L)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
STAFFORD TELLWICK
STEEL BRIDGE
S.P.&S. R.R. BRIDGE
LEGEND:
JUNE 22-23 SURVEY
JULY 27-28 SURVEY
AUG. 9-10 SURVEY
20
15
10
5
0
RIVER MILES UPSTREAM OF MOUTH

FIGURE - 1

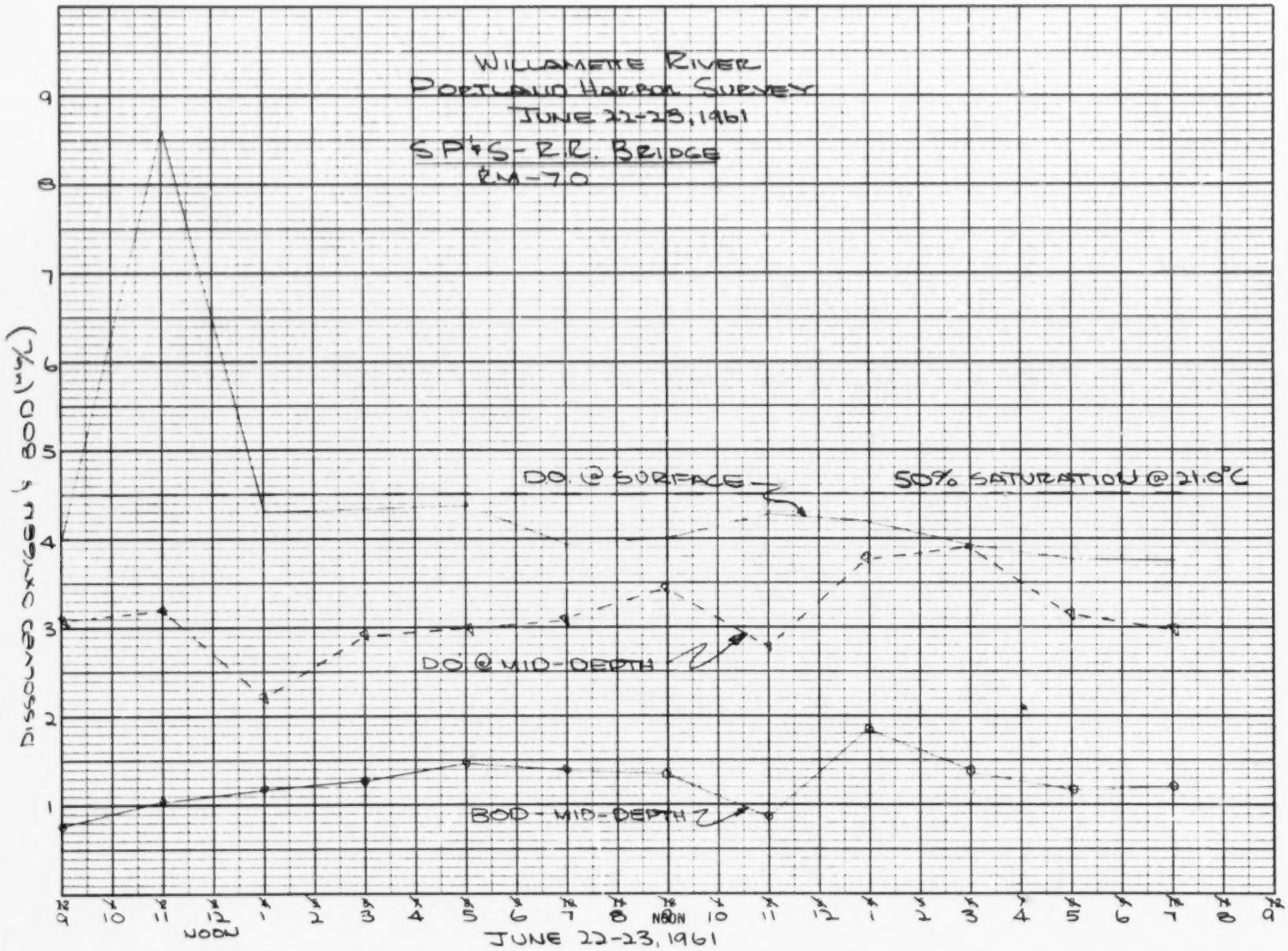

143 PPM
PBI
BOD
Steel Bridge
Burnside Bridge
Ross Island Bridge
Leaburg
Portland Harbor (Willamette River) 1961
PBI - BOD (MEAN) AT MID-DEPTH
BOD (mg/L)
PEARSE-BENGEN INDEX (ppm)
RIVER MILES - UPSTREAM OF MOUTH

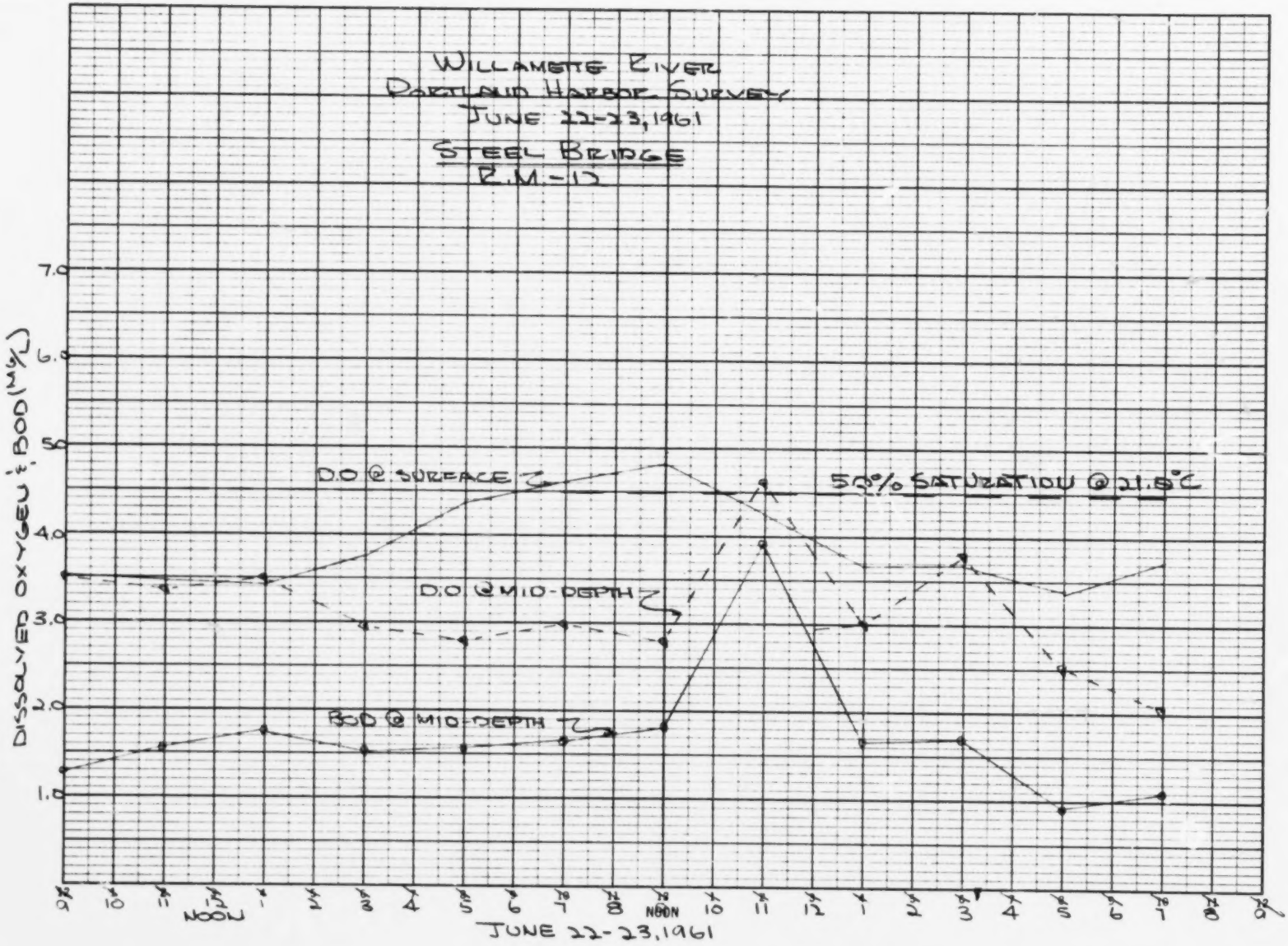
Dissolved Oxygen
Portland Harbor
Lower Willamette River
1958-1961
Average Mid-depth D.O.'s
of 3 Diurnal Surveys
1958
1959
1960
1961
Observed Stages Saturation
Apparent D.O. Deficit
Dissolved Oxygen
Saturation
Willamette - River Miles
Figure - 3

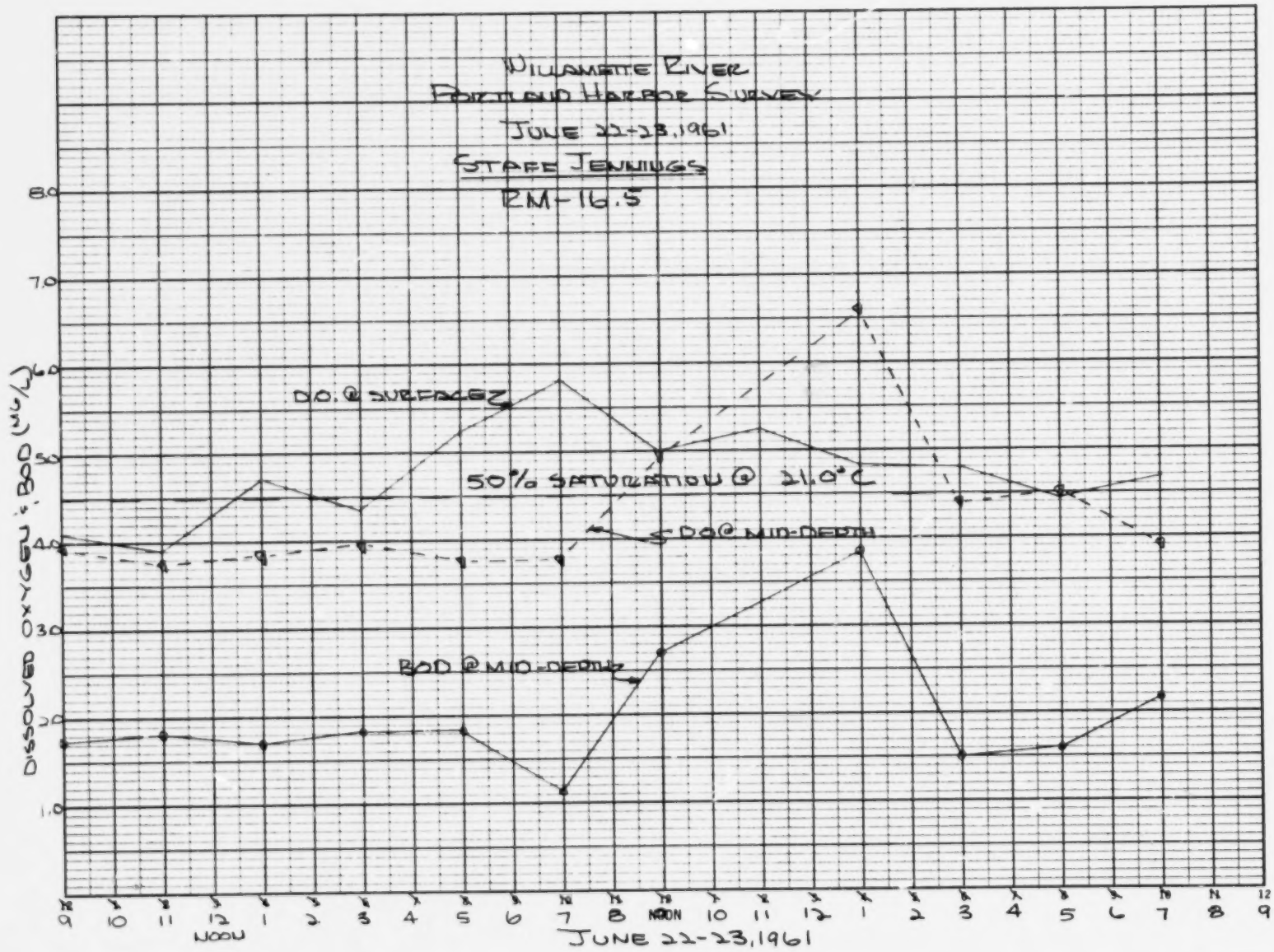

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
WILLAMETTE RIVER
AT
SALEM, OREGON
SUMMER - 1961
15,000
10,000
5,000
DISCHARGE (CFS)
JUNE 22-23 SURVEY
JULY 27-28 SURVEY
AUGUST 9-10 SURVEY

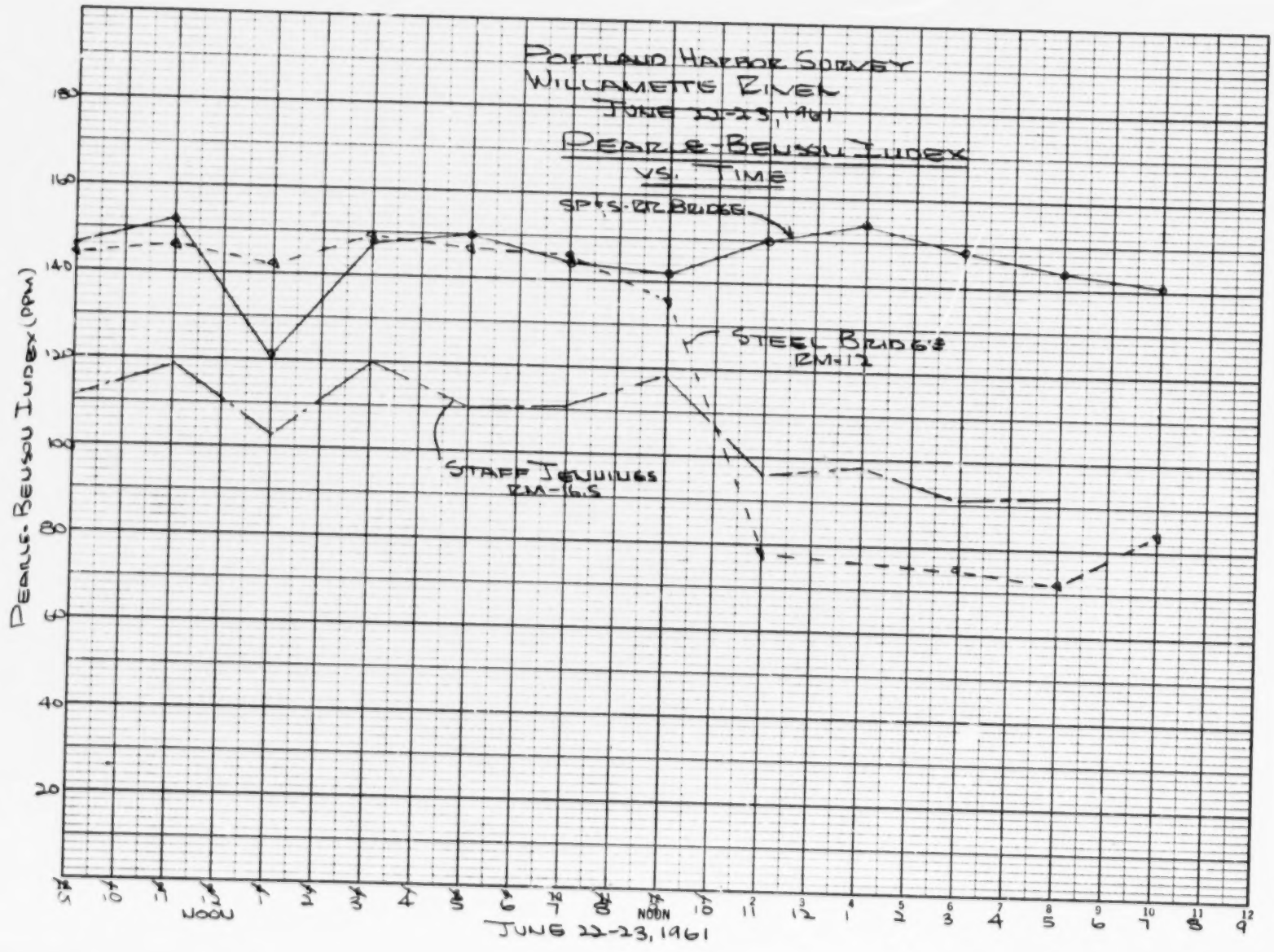
-1961-

JUNE 22-23 SURVEY


WILLAMETTE RIVER
PORTLAND HARBOR SURVEY
JUNE 22-23, 1961
SP&S - R.R. BRIDGE
RM - 7.0
DO @ SURFACE
50% SATURATION @ 21.0°C
DO @ MID-DEPTH
BOD - MID-DEPTH
DISSOLVED OXYGEN & BOD (mg/l)
NOON
NOON
JUNE 22-23, 1961


WILLAMETTE RIVER
PORTLAND HARBOR SURVEY
JUNE 22-23, 1961
STEEL BRIDGE
R.M.-12
DISSOLVED OXYGEN & BOD (MG/L)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
D.O @ SURFACE
50% SATURATION @ 21.5°C
D.O @ MID-DEPTH
BOD @ MID-DEPTH
9P
10
11
NOON
1
2
3
4
5
6
7
8
9
NOON
10
11
12
1
2
3
4
5
6
7
8
9
10
JUNE 22-23, 1961


WILLAMETTE RIVER
PORTLAND HARBOR SURVEY
JUNE 22-23, 1961
STAFF JENNINGS
RM-16.5
DISSOLVED OXYGEN & BOD (MG/L)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
D.O. @ SURFACE
50% SATURATION @ 21.0°C
D.O. @ MID-DEPTH
BOD @ MID-DEPTH
9 10 11 12 1 2 3 4 5 6 7 8 NOON 10 11 12 1 2 3 4 5 6 7 8 9
NOON
JUNE 22-23, 1961


PORTLAND HARBOR SURVEY
WILLAMETTE RIVER
JUNE 22-23, 1961
PEARL-BELLOU INDEX
VS. TIME
SP&S-RR BRIDGE
STEEL BRIDGE
RM 12
STAFF ISLANDS
RM-16.5
PEARL-BELLOU INDEX (PPM)
180
160
140
120
100
80
60
40
20
NOON
NOON
JUNE 22-23, 1961

PORTLAND HARBOR SURVEY
June 22-23, 1961

SP&S R.R. BRIDGE

Time	Temp °C		pH		D.O. (PPM)		B.O.D. (PPM)	S.W.L. (PPM)	Cond. (μmho's) cm
	S	M	S	M	S	M			
0900	21.0	20.0			4.0	3.1	0.76	146	78
1100	22.0	20.0			8.6	3.2	1.04	152	80
1300	23.5	22.0			4.3	2.2	1.18	122	90
1500	24.0	22.5			2.2	2.9	1.28	148	82
1700	24.0	22.5		6.4	4.4	3.0	1.47	150	73
1900	24.0	22.0		6.3	3.95	3.1	1.40	144	80
2100	22.5	21.0	7.8	6.8	4.0	3.45	1.32	142	75
2300	22.5	20.0	6.2	6.3	4.3	2.8	0.86	150	77
0100	21.5	20.0	6.2	6.3	4.2	3.8	1.87	154	74
0300	21.5	20.5	6.2	6.1	3.9	3.9	1.38	148	74
0500	21.0	20.0	6.1	5.6	3.8	3.2	1.12	144	76
0700	21.0	20.5	6.1	5.9	3.75	3.0	1.22	141	80

Temp °C, pH, and D.O.(PPM) were taken at surface and mid-depth.
B.O.D.(PPM), S.W.L.(PPM), and Cond. were taken at mid-depth only.

PORTLAND HARBOR SURVEY
June 22-23, 1961

STEEL BRIDGE

Time	Temp °C		pH		D.O. (PPM)		B.O.D. (PPM)	S.W.L. (PPM)	Cond. (μmho's) cm
	S	M	S	M	S	M			
09:00	21	21			3.5	3.5	1.30	144	80
11:00	22	22			3.5	3.4	1.54	146	75
13:00	23.5	23.5			3.4	3.5	1.78	142	76
15:00	24	23.5			3.8	3.0	1.52	149	75
17:00	24.5	23		6.6	4.4	2.8	1.58	147	73
19:00	24	23		6.4	4.6	3.0	1.67	145	74
21:00	23	21.5	6.3	6.2	4.8	2.8	1.82	135	73
23:00	22	19.5	6.2	6.3	4.3	4.6	3.90	78	83
01:00	21.5	21.0	6.4	6.2	3.7	3.0	1.63	-	-
03:00	21	18	5.9	6.0	3.7	3.75	1.67	75	88
05:00	21.5	18.0	6.0	5.9	3.4	2.5	0.88	72	87
07:00	21.0	18.0	5.9	5.9	3.75	2.0	1.08	84	79

Temp °C, pH, and D.O.(PPM) were taken at surface and mid-depth.
B.O.D.(PPM), S.W.L.(PPM), and Cond. were taken at mid-depth only.

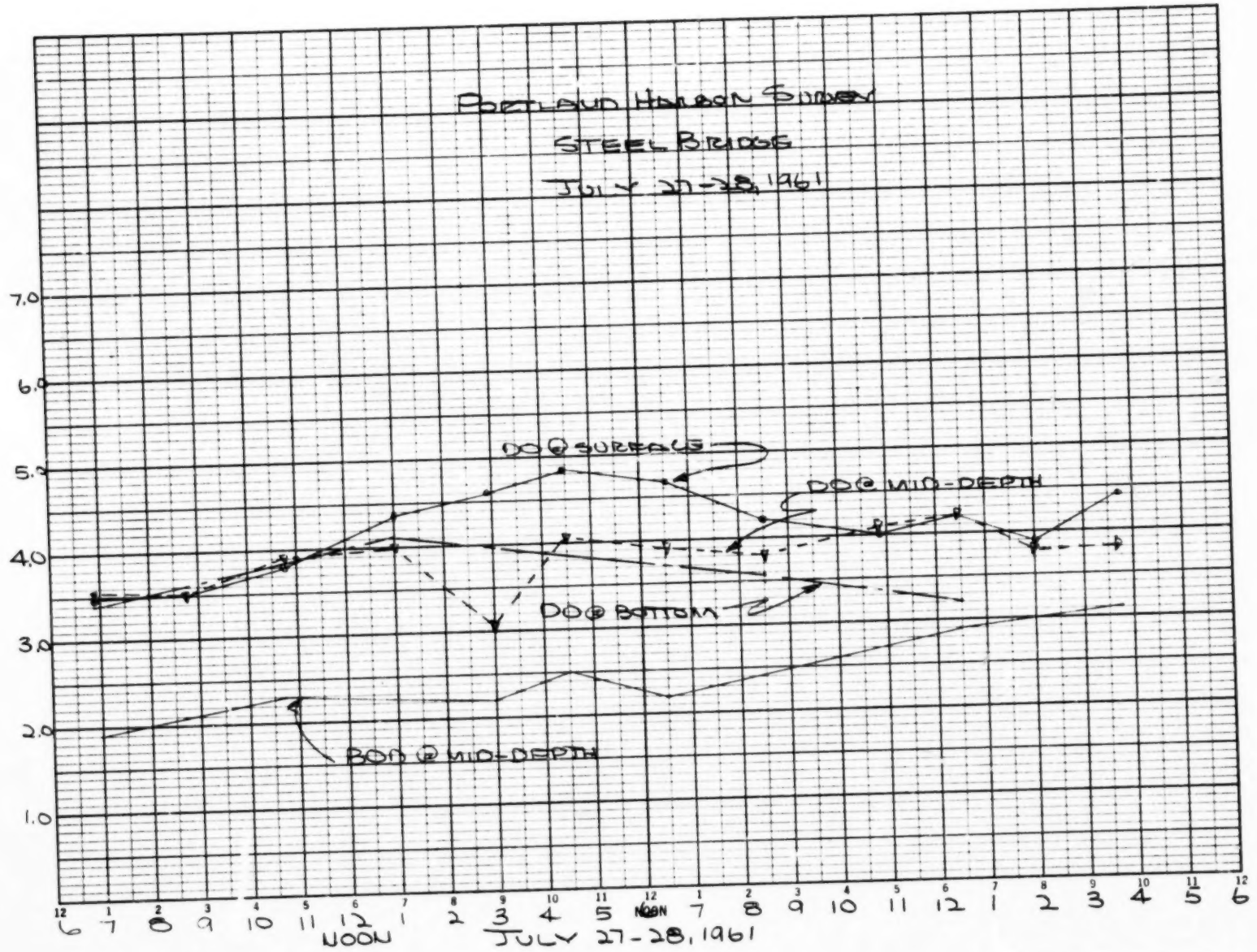
PORTLAND HARBOR SURVEY
June 22-23, 1961

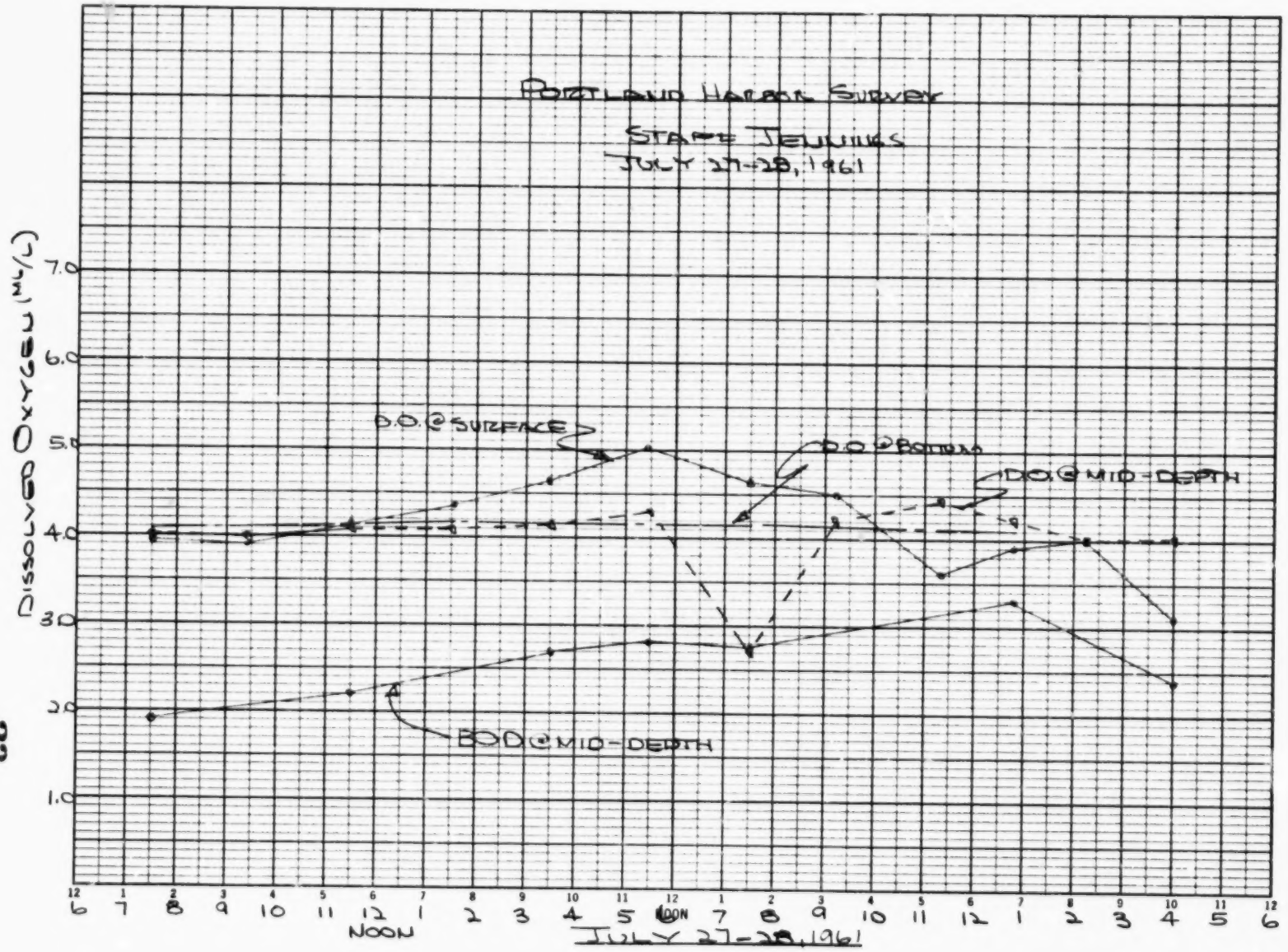
STAFF JENNINGS

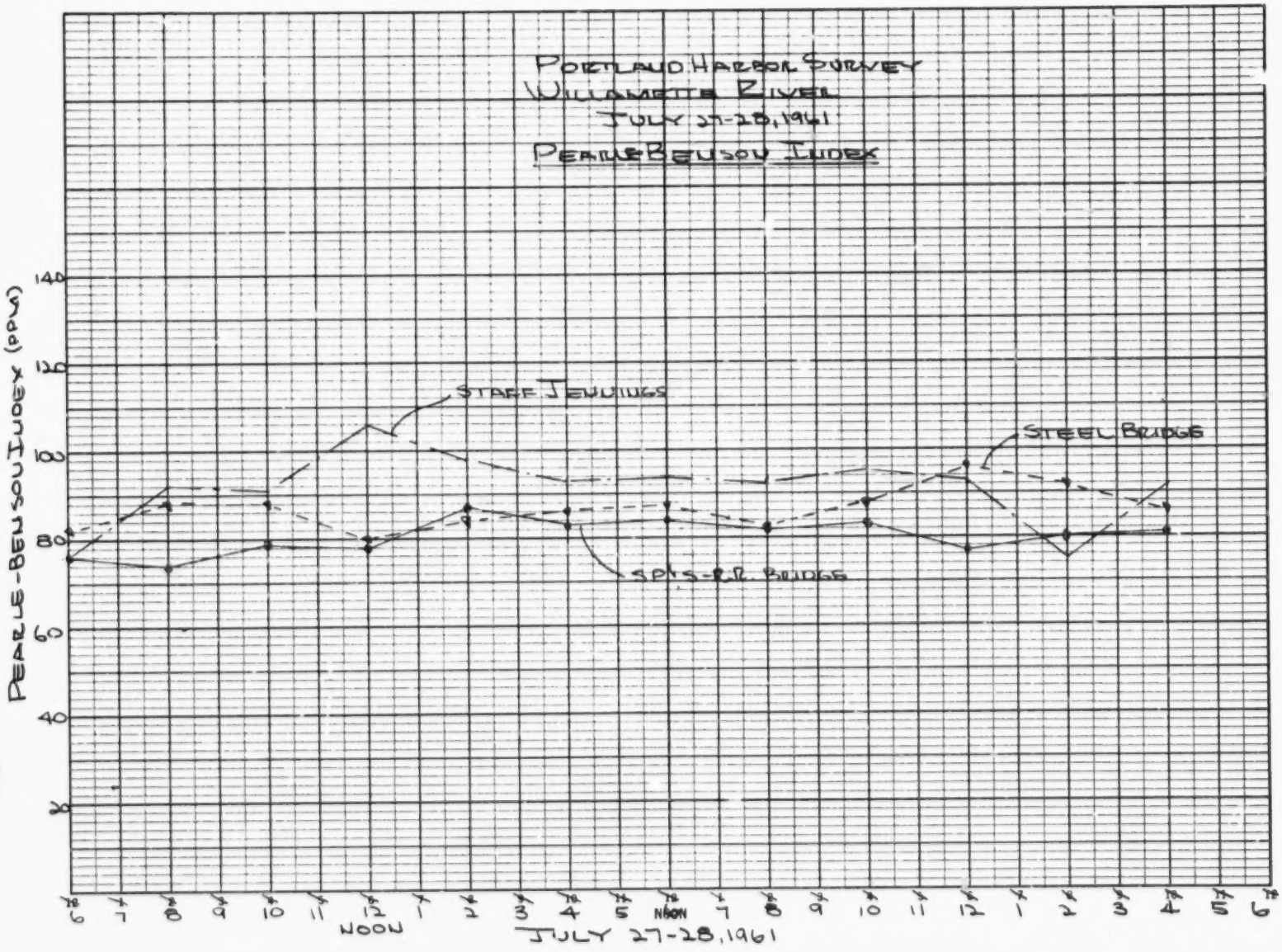
Time	Temp °C		pH		D.O. (PPM)		B.O.D. (PPM)	S.W.L. (PPM)	Cond. (μmho's) cm
	S	M	S	M	S	M			
0900		22.0			4.1	4.0	1.78	111	70
1100	23.0	23.0			3.9	3.8	1.82	119	81
1300	24.0	24.0			4.7	3.9	1.73	113	78
1500	24.0	24.0		6.8	4.35	4.0	1.85	120	79
1700	24.0	23.0		6.4	5.2	3.8	1.88	110	75
1900	24.0	23.0	6.5	6.4	5.8	3.8	1.17	111	70
2100	22.0	22.0	7.2	7.0	5.0	5.0	2.73	118	70
2300	22.0	21.5	6.4	6.3	5.2	-	-	96	70
0100	21.5	21.5	6.2	6.1	4.8	6.6	3.86	98	70
0300	21.0	21.0	6.3	5.8	4.75	4.4	1.50	91	67
0500	21.0	21.0	5.8	6.1	4.4	4.5	1.57	92	72
0700	21.0	21.0	6.2	6.1	4.6	3.9	2.17	-	-

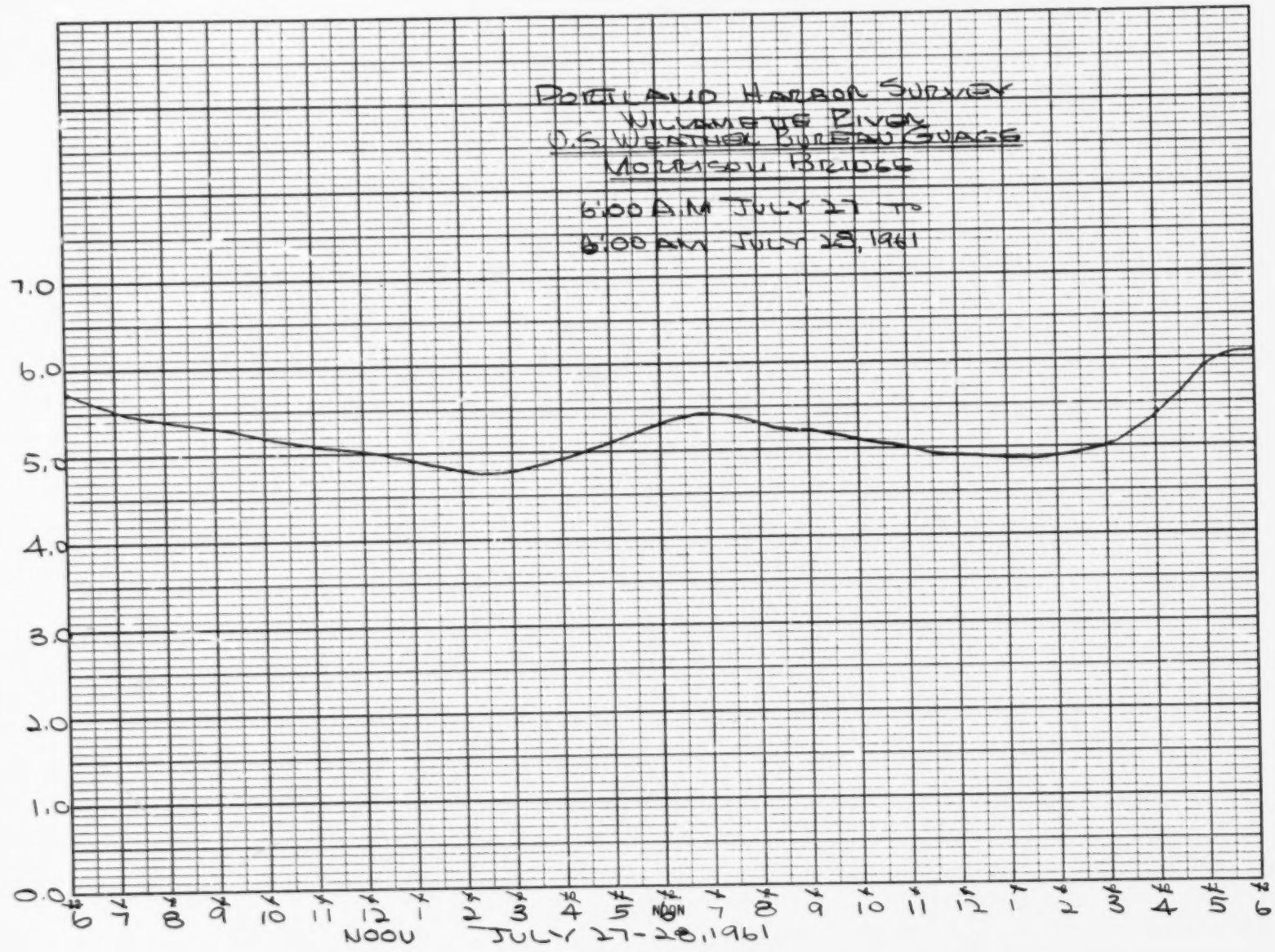
Temp °C, pH, and D.O.(PPM) were taken at surface and mid-depth.
B.O.D.(PPM), S.W.L.(PPM), and Cond. were taken at mid-depth only.

JULY 27-28 SURVEY


PORTLAND HARBOR SURVEY
STEEL BRIDGE
JULY 27-28, 1961
7.0
6.0
5.0
4.0
3.0
2.0
1.0
DO @ SURFACE
DO @ MID-DEPTH
DO @ BOTTOM
BOD @ MID-DEPTH
12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6
NOON
NOON
JULY 27-28, 1961


PORTLAND HARBOR SURVEY
STATE JENNINGS
JULY 27-28, 1961
DISSOLVED OXYGEN (ML/L)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
D.O. @ SURFACE
D.O. @ BOTTOM
D.O. @ MID-DEPTH
BOD @ MID-DEPTH
12 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6
NOON
NOON
JULY 27-28, 1961


PORTLAND HARBOR SURVEY
WILLAMETTE RIVER
JULY 27-28, 1961
PEARLE BENSON INDEX
PEARLE-BENSON INDEX (ppm)
140
120
100
80
60
40
20
STAFF JENNINGS
STEEL BRIDGE
SP'S-P.R. BRIDGE
6 7 8 9 10 11 12 1 2 3 4 5 NOON 7 8 9 10 11 12 1 2 3 4 5 6
NOON
JULY 27-28, 1961


PORTLAND HARBOR SURVEY
WILLAMETTE RIVER
U.S. WEATHER BUREAU GUAGE
MORRISON BRIDGE
6:00 A.M JULY 27 TO
6:00 AM JULY 28, 1961
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6 7 8 9 10 11 12 1 2 3 4 5 NOON 7 8 9 10 11 12 1 2 3 4 5 6
NOON
JULY 27-28, 1961

PORTLAND HARBOR SURVEY
July 27-28, 1961

SP&S R.R. BRIDGE

Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0610	21.2	21.1	20.5				3.15	2.90	3.67	1.9	76
0807	22.1	22.3					2.80	2.70			74
1010	22.5	22.5					2.90	2.70		1.6	79
1200	23.4	23.0	22.8				4.10	2.77	2.50		78
1415	24.2	23.3					3.40	2.80		1.6	87
1600	23.9	23.2		6.6	6.6		3.25	2.87		2.1	83
1809	24.1	23.2	22.6	6.7	6.7	6.8	3.70	2.67	2.80	1.7	84
2006	23.3	22.9		6.6	6.6		3.5	2.68			82
2217	22.8	22.8		6.6	6.6		2.80	2.93			83
2400	22.4	22.7	22.9	6.3	6.7	6.5	3.20	3.50	1.80	2.8	77
0135	22.8	22.8		6.2	6.3		2.5	2.9			80
0325	22.7	22.7		6.2	6.2		2.8	2.7		2.2	81

Temp °C, pH, and DO(PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) and SWL(PPM) were taken at mid-depth only.

PORTLAND HARBOR SURVEY
July 27-28, 1961

STEEL BRIDGE

Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0650	22.2	21.2	21.5				3.48	3.55	3.40	1.9	82
0845	21.5	22.2					3.50	3.50			88
1045	22.7	22.3					3.80	3.90		2.3	88
1300	23.1	23.0	22.8				4.35	4.0	4.10		80
1455	23.5	23.2		6.7	6.7		4.60	3.05		2.2	84
1622	23.5	23.1		6.6	6.7		4.81	4.05		2.5	86
1834	23.5	22.9	23.0	6.7	6.7	6.7	4.67	3.9	3.6	2.2	87
2028	22.8	22.8		6.7	6.7		4.20	3.80			82
2242	22.5	22.6		6.6	6.6		4.0	4.10			88
0025	22.3	22.6	22.9	6.7	6.6	6.6	4.20	4.2	3.7	2.9	96
0200	22.5	22.8		6.4	6.5		3.9	3.8			92
0345	22.6	22.6		6.4	6.6		4.4	3.8		3.1	86

Temp °C, pH, and DO(PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) and SWL(PPM) were taken at mid-depth only.

PORTLAND HARBOR SURVEY
July 27-28, 1961

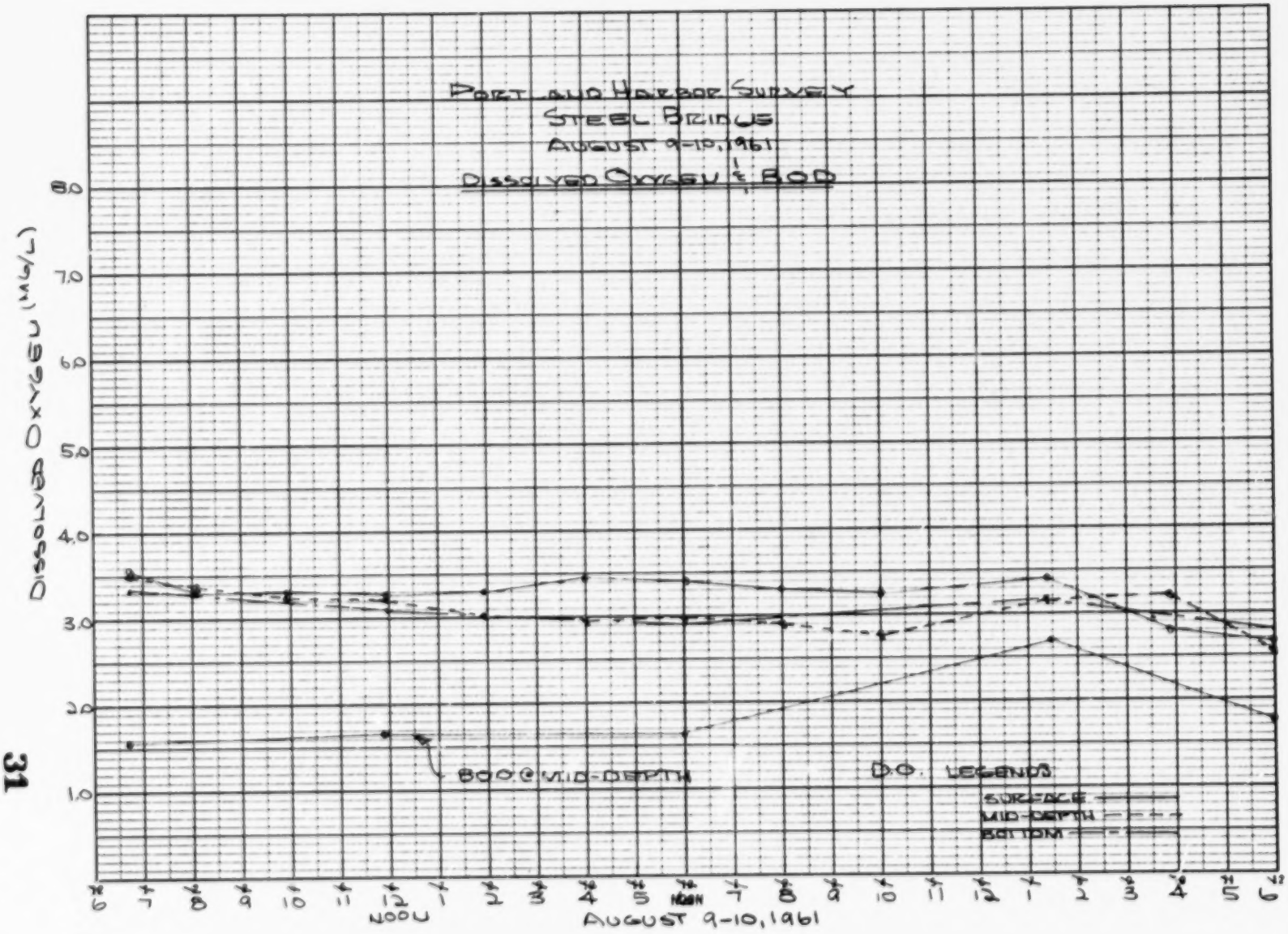
STAFF JENNINGS

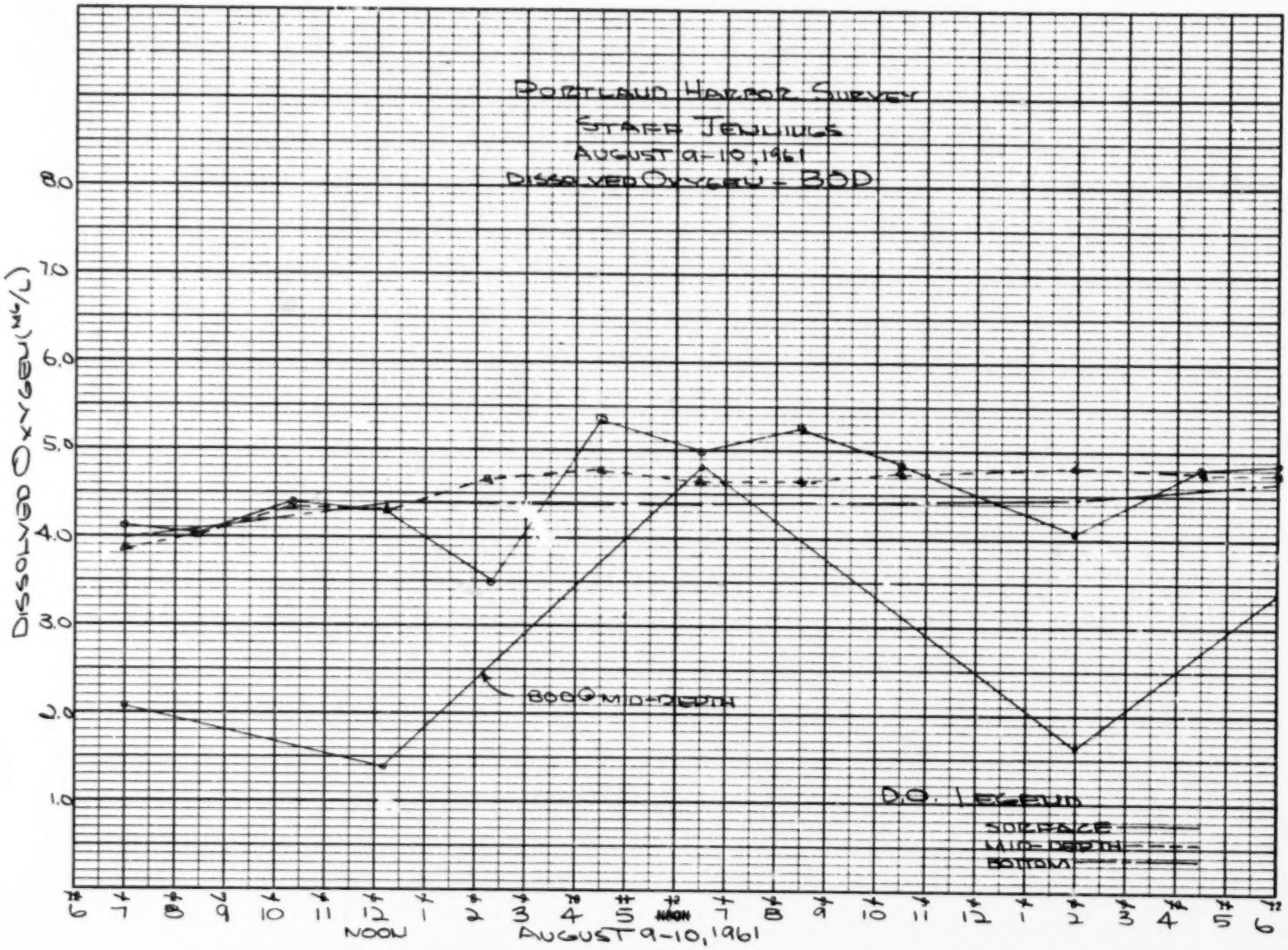
Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0730	22.2	22.2	22.3				3.95	3.98	4.05	1.9	76
0925	21.5	22.8					3.90	4.00			92
1130	23.0	22.7					4.13	4.10		2.2	91
1325	23.0	23.0	23.0	4.			4.35	4.10	4.15		106
1520	23.5	23.3		6.7	6.7		4.65	4.12		2.7	98
1720	23.6	23.2		6.7	6.7		5.03	4.30		2.8	93
1930	23.3	22.9	23.0	6.6	6.7	6.6	4.62	2.7	4.12	2.7	94
2115	22.9	22.8		6.7	6.7		4.50	4.20			93
2320	22.6	22.9		6.4	6.3		3.60	4.40			95
0045	22.8	22.7	23.1	6.6	6.6	6.6	3.9	4.2	4.1	3.3	93
0215	22.7	22.9		6.5	6.5		4.0	4.0			75
0400	22.6	22.7		6.5	6.5		3.1	4.0		2.4	92

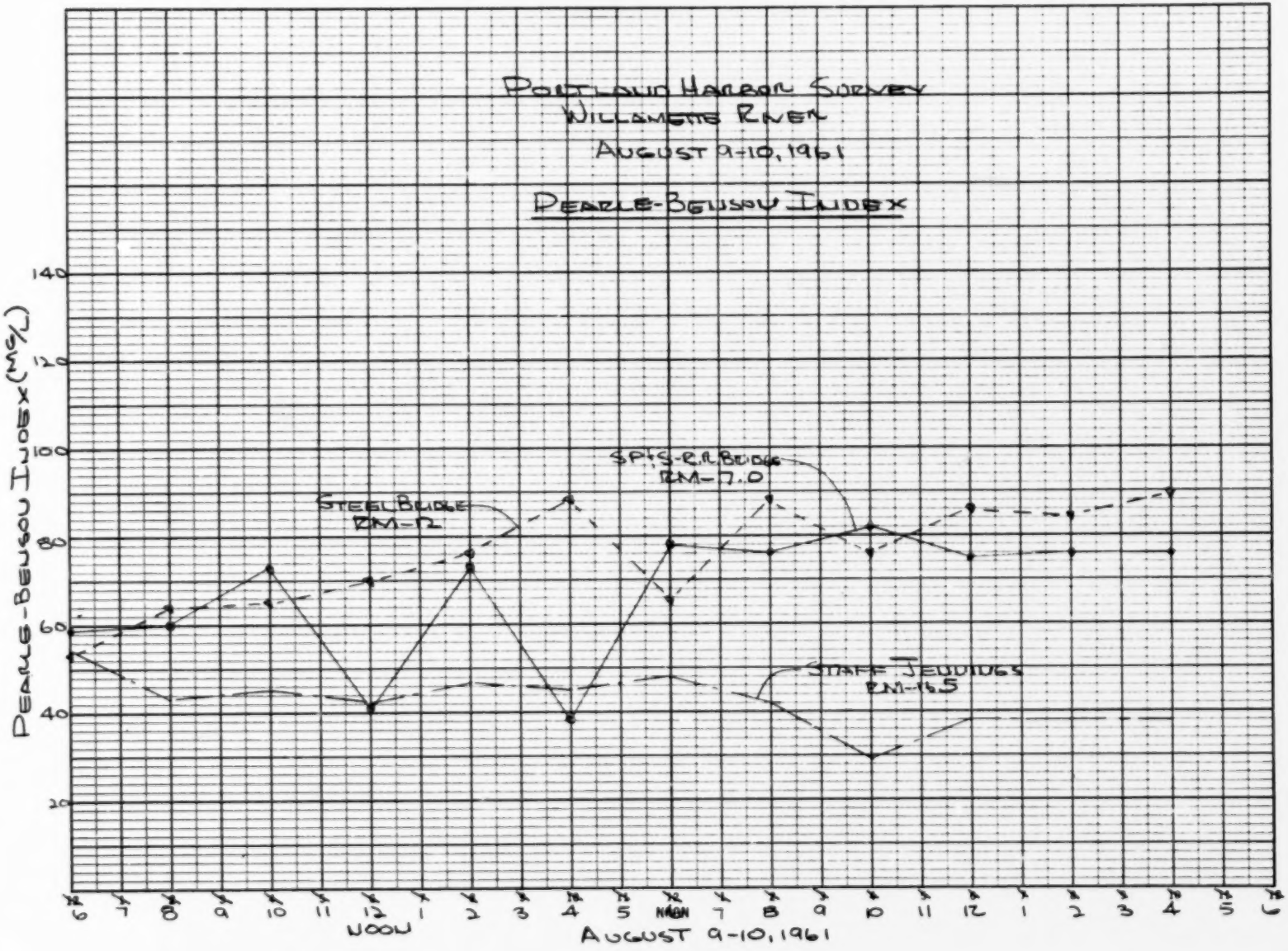
Temp °C, pH, and DO (PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) and SWL(PPM) were taken at mid-depth only.

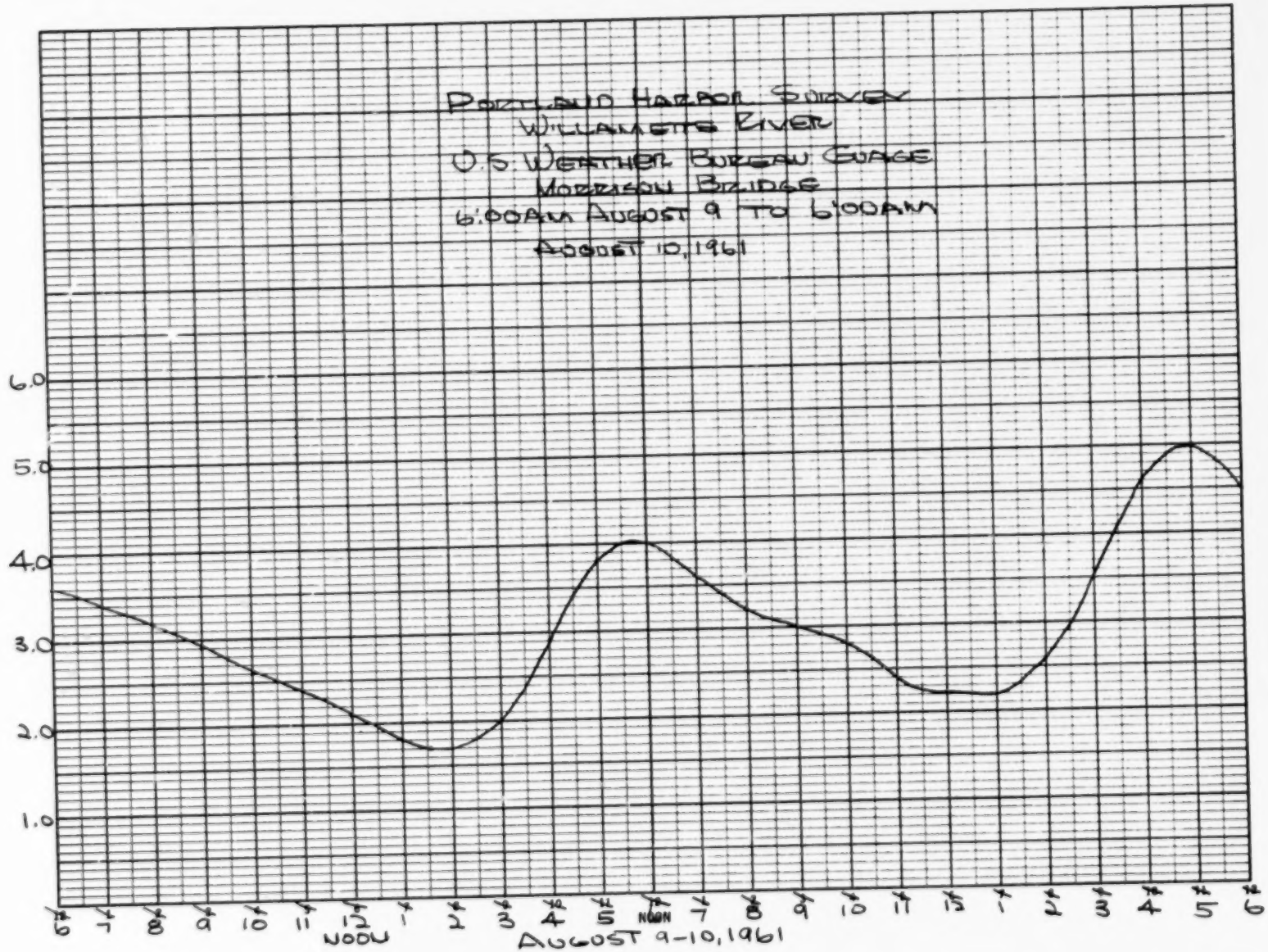
AUGUST 9-10 SURVEY

Portland Harbor Survey - Willamette R.
SP&S + RR. Bridge
August 9-10, 1961
Dissolved Oxygen
and
B.O.D.
LEGEND:
SURFACE
MID-DEPTH
BOTTOM
BOD @ MID-DEPTH
D.O. (mg/l)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
August 9-10, 1961


PORT AND HARBOR SURVEY
STEEL BRIDGE
AUGUST 9-10, 1961
DISSOLVED OXYGEN & BOD
DISSOLVED OXYGEN (MG/L)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
BOD @ MID-DEPTH
D.O. LEGENDS:
SURFACE
MID-DEPTH
BOTTOM
6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6
NOON
MIDN
AUGUST 9-10, 1961


PORTLAND HARBOR SURVEY
STAFF JENKINS
AUGUST 9-10, 1961
DISSOLVED OXYGEN - BOD
DISSOLVED OXYGEN (MG/L)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
BOD @ MID-DEPTH
D.O. LEGEND
SURFACE
MID-DEPTH
BOTTOM
6 7 8 9 10 11 12 1 2 3 4 5 NOON 7 8 9 10 11 12 1 2 3 4 5 6
AUGUST 9-10, 1961


PORTLAND HARBOR SURVEY
WILLAMETTE RIVER
AUGUST 9-10, 1961
PEARLE-BEUSOU INDEX
PEARLE-BEUSOU INDEX (MG/L)
140
120
100
80
60
40
20
STEEL BRIDGE
RM-12
SP&S-R.R. BRIDGE
RM-7.0
STAFF JEUDIDGE
RM-16.5
6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5
NOON
MIDNIGHT
AUGUST 9-10, 1961


PORTLAND HARBOR SURVEY
WILLAMETTE RIVER
U.S. WEATHER BUREAU GUAGE
MORRISON BRIDGE
6:00AM AUGUST 9 TO 6:00AM
AUGUST 10, 1961
6.0
5.0
4.0
3.0
2.0
1.0
6 7 8 9 10 11 12 1 2 3 4 5 NOON 7 8 9 10 11 12 1 2 3 4 5 6
NOON
AUGUST 9-10, 1961

PORTLAND HARBOR SURVEY
August 9-10, 1961

SP&S R.R. BRIDGE

Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0615	21.9	21.9	22.6	6.6	6.7	6.7	2.45	2.60	2.55	1.53	59
0745	22.4	22.5		6.5	6.4		2.30	2.30			60
0930	22.3	22.6		6.6	6.5		2.50	2.40			73
1125	22.5	22.1	22.6	6.4	6.3	6.4	2.50	2.24	2.11	1.51	41
1325	23.1	22.8		6.9	6.9		2.30	2.38			73
1530	24.5	23.2		7.0	7.2		2.62	2.20			38
1730	23.5	23.3	23.0	7.1	7.2	7.2	2.60	2.33	2.10	1.78	78
1930	23.5	23.0		7.0	7.1		2.90	2.15			76
2130	23.0	23.0		6.8	6.9		2.62	2.43			82
0045	22.8	22.5	22.7	8.8	6.6	6.6	3.30	2.28	2.17	1.42	75
0325	22.4	22.7		6.5	5.8		1.95	2.15			76
0538	22.3	22.7	22.7	5.3	5.4	5.3	2.08	2.42	2.18	1.07	76

Temp °C, pH, and DO(PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) and SWL(PPM) were taken at mid-depth only.

PORTLAND HARBOR SURVEY
August 9-10, 1961

STEEL BRIDGE

Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0645	22.1	21.9	22.4	6.5	6.6	6.5	3.55	3.50	3.35	1.53	53
0805	22.2	22.5		6.6	6.4		3.30	3.38			64
0950	22.2	22.5		6.8	6.6		3.30	3.25			65
1150	22.3	22.3	22.6	6.6	6.5	6.6	3.25	3.22	3.10	1.65	70
1350	22.8	22.8		6.6	6.5		3.30	3.00			76
1600	23.3	22.9		7.3	7.3		3.45	2.95			88
1810	23.3	23.2	22.9	7.2	7.2	7.1	3.40	2.98	2.95	1.62	65
2000	23.1	23.0		7.2	7.2		3.30	2.90			88
2200	22.9	22.9		6.9	6.9		3.25	2.75			76
0120	22.6	22.8	22.8	6.5	6.6	7.0	3.40	3.13	3.15	2.70	86
0355	22.4	22.6		6.2	5.9		2.80	3.20			84
0605	22.2	22.7	22.5	4.8	5.3	5.3	2.67	2.58	2.80	1.74	89

Temp °C, pH, and DO(PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) AND SWL(PPM) were taken at mid-depth only.

PORTLAND HARBOR SURVEY
August 9-10, 1961

STAFF JENNINGS

Time	Temp °C			pH			DO (PPM)			BOD (PPM)	SWL (PPM)
	S	M	B	S	M	B	S	M	B		
0710	22.3	22.4	22.7	6.6	6.7	6.7	4.12	3.88	4.00	2.08	54
0825	22.3	22.5		6.6	6.5		4.05	4.02			43
1020	22.2	22.4		6.7	6.6		4.40	4.35			45
1215	22.3	22.3	22.5	6.6	6.8	6.8	4.30	4.30	4.45	1.39	42
1420	22.8	22.7		6.7	6.9		3.50	4.65			47
1630	23.4	23.0		7.4	7.3		5.35	4.75			45
1830	23.4	23.1	23.0	7.2	7.2	7.3	5.00	4.62	4.40	4.80	48
2030	23.0	22.9		7.0	6.8		5.25	4.65			42
2225	22.7	22.7		6.6	6.8		4.85	4.73			30
0150	22.7	22.8	22.8	6.7	6.9	6.9	4.03	4.80	4.47	1.63	38
0430	22.4	22.6		5.5	5.8		4.80	4.80			38
0630	22.3	22.7	22.7	4.9	5.3	5.5	4.83	4.77	4.57	3.38	38

Temp °C, pH, and DO(PPM) were taken at surface, mid-depth and bottom.
BOD(PPM) and SWL(PPM) were taken at mid-depth only.